

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 10 in the underlying PCT Application No. PCT/DE03/01032. This Preliminary Amendment adds new claims 11-20. The new claims, *inter alia*, conform the claims to United States Patent and Trademark Office rules and do not add new matter to the application


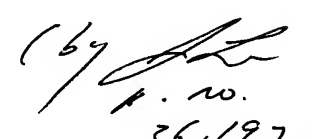
In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(ii) and § 1.125(c), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/01032 includes an International Search Report, dated September 12, 2003, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
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INTERFEROMETRIC MEASURING DEVICE

5 Field of the Invention

The present invention relates to an interferometric measuring device for recording the shape, the roughness or the distance to the surface of a measured object, using a modulation interferometer to which short-coherent radiation is supplied
10 ~~by a radiation source and which has a first beam splitter for splitting the radiation supplied into a first beam component guided via a first arm, and into a second beam component guided via a second arm, of which the one is shifted with respect to the other with the aid of a modulating device in~~
15 ~~its light phase or light frequency, and passes through a delay line, and which subsequently are united at an additional beam splitter of the modulation interferometer, and having a measuring probe, that is spatially separated from the modulation interferometer and is coupled or able to be coupled~~
20 ~~to the latter via an optical fiber device, in which the combined beam components are split up into a measuring beam that is guided to the surface by a probe optical fiber unit having a slantwise exit surface at the object end, and a reference beam, and whereupon the measuring beam reflected at~~
25 ~~the surface and the reference beam reflected at a reference plane are superimposed, and having a receiver device and an evaluating unit for converting the radiation supplied to it into electrical signals and for evaluating the signals on the basis of a phase difference.~~

30 ~~Background Information~~ Background Information

~~Such an~~In an interferometric measuring device ~~is described in~~
published German patent document DE 100 57 539 A1. ~~In this~~
~~known measuring device,~~ the interferometric measuring device
is subdivided, on the one hand, into a modulation

5 interferometer and, on the other hand, into a measuring probe
having an additional interferometer unit. In the measuring
probe there is provided a probe-optical fiber unit having an
exit surface at the object end which, for instance, may be
beveled. ~~No more precise statements are made with respect to~~
10 ~~this.~~ By the way, such an interferometric measuring device
works in a manner described in greater detail in ~~connection~~
~~with~~published German Patent document DE 198 19 762 A1.

~~An~~In an additional interferometric measuring device ~~is given~~
~~described in~~ published German patent document DE 198 19 762
15 ~~A1. In this known measuring device,~~ one part, the so-called
modulation interferometer, is spatially separated from the
actual measuring probe, and is optically connected to it via a
light-conducting fiber system, so that the measuring probe ~~per~~
~~se~~ may be designed as a relatively simply constructed, easily
20 manipulable unit. A broad-band, short-coherent radiation is
supplied to the modulation interferometer, which is split into
two beam components at the input of the modulation
interferometer with the aid of a beam splitter, of which the
one is shifted in its light phase or light frequency with
25 respect to the other, using a modulation device, such as an
~~acousto-optic~~electro-optic modulator. In the modulation
interferometer, one of the two beam components runs through a
delay element which generates an optical path difference of
the two beam components which is greater than the coherence
30 length of the short-coherent radiation. In the measuring
probe, in a measuring arm, with respect to a reference arm, an
additional optical path difference is generated in such a way
that the path difference effected by the delay element is

compensated for, and, consequently, an interference is created ~~eff~~between the reference radiation coming from the reference plane of the reference arm and the radiation coming back from the object surface in the measuring arm, which interference is subsequently analyzed so as to ascertain the desired surface property (shape, roughness, clearance distance) via a phase evaluation. In the measuring probe, the measuring arm and the reference arm are situated in one exemplary embodiment in one common light path (common path), a partially transmitting optical element being provided for forming the measuring arm and the reference arm.

A similar interferometric measuring device having such a modulation interferometer and a measuring probe connected to it via a light-conducting fiber system is also described in published German patent document DE 198 08 273 A1, in. In a beam splitting and radiation detecting unit, using a receiving equipment, ~~a splitting of the radiation brought to interference~~ is split into radiation components of different ~~wavelength taking place~~ wavelengths, so as to form therefrom a synthetic wavelength and to increase the measuring range ~~(range of unambiguity)~~.

In the interferometric measuring devices named above, which are based on heterodyne interferometry, but which utilize the properties of a broad-band, short-coherent radiation, the modulation interferometer, designed as a Mach-Zehnder interferometer, has a system of classical optical components, such as collimation optics lying upstream of the input end of the beam splitter, with the beam splitter and reflecting mirror at the input end and the output end, respectively. In this context, the beam components experience several reflections at the beam splitter surfaces and at the mirrors, before they are coupled ~~in to~~ into the optical light-conducting fiber system. The optical components have to be positioned

with great accuracy, since the effect of every angle error is doubled by the reflection. In this context, it is difficult to ensure the durability of a calibration. In connection with fitting in a glass plate to compensate for optical

5 asymmetries, ~~too~~, additional difficulties come about during the calibration. A costly construction is connected with these difficulties, an exact adjustment to the properties of the measuring probe being also required.

10 ~~The~~An object of the present invention is ~~based on the object~~ of making available an interferometric measuring device ~~of the type mentioned at the outset,~~ which permits achieving as accurate as possible a measurement, using a simplified construction.

~~Summary of the Invention~~ Summary

15 ~~This object is attained by the features set forth in Claim 1.~~ According to ~~this~~the present invention, it is provided that the angle of inclination of the exit surface of the probe-optical fiber unit with respect to the normal of the optical probe axis is at least 46° .

20 Using this design of the exit surface, one achieves an optimal coupling behavior in the case of right-angled beam deflection in this transitional region of the measuring beam guided to the surface of the measured object and returning from it, whereby the accuracy of the measurement is
25 substantially favored, especially in inaccessible, tight hollow spaces.

An additional improvement, ~~especially in the case of a numerical aperture of the respective optical fiber of 0.12,~~ is may be achieved by making the angle of inclination at least
30 48° .

Furthermore, interferences are suppressed by providing a jacket-like covering of an object-end end-section of the probe optical fiber unit with an anti-reflection treatment.

5 ~~Further possibilities for improving~~Additional improvement to
the coupling of the radiation ~~are to provide~~may be achieved by
providing the exit surface with a reflection treatment.

~~For the construction and the functioning, one~~An example
embodiment of the present invention is advantageous in that a
10 partially transmitting region between a probe fiber and a
fiber section of the measuring probe is formed with the aid of
an exit surface of a probe fiber that is slanted at an exit
angle with respect to the optical probe axis, and with the aid
of an entrance surface of a fiber section following on the
object end that is also slanted at an exit angle with respect
15 to the optical probe axis,~~between.~~ Furthermore, a wedge-
shaped gap is formed between the exit surface and the entrance
surface ~~a wedge-shaped gap being formed,~~ and the exit surface
and the entrance surface ~~being~~ are inclined in the same
direction with respect to the probe axis.

20 In this regard, it is advantageous ~~measures are~~ that the exit
angle and the entrance angle are selected so that a Fresnel
reflection is effected. The radiation transmission for
reliable measuring results is favored by the exit angle α
being between 5° and 8° , and the entrance angle being between
25 α and 0° .

An additional advantageous ~~construction is~~example embodiment
provides that the probe fiber and the fiber section are
accommodated axially aligned in a tubule-shaped accommodation,
which is surrounded by an outer tube of the measuring probe,
30 ~~that on.~~ On the end face of the accommodation, that faces
away from the measured object, a positioning element is

provided that surrounds the probe fiber and is also accommodated concentrically to the tube, and ~~that the fiber section is fixed in the object-end, front part of the accommodation,~~ and the probe fiber is fixed in the rear part of the accommodation, that is distant from the object, and/or in the tube.

Furthermore, one favorable ~~construction~~example embodiment is achieved in that the front part of the accommodation is separated from the rear part of the accommodation by diametrically opposite gaps, ~~the one gap being limited at the rear in the elongation of the slanted exit surface of the probe fiber, and the other gap being limited on the front in the elongation of the slanting entrance surface, that.~~ In addition, the front part and the rear part of the receptacle are enclosed by a common sleeve-shaped retaining ring, which is surrounded on the outside by the tube, and that a front section of the fiber section has a ~~lessers~~smaller diameter compared to its rear section.

~~Other measures contribute to an advantageous construction and reliable functioning, namely~~Another example embodiment provides that the modulation interferometer has at least partially a polarization-maintaining, light-conducting structure in the form of an optical fiber conductor or integrated optics, the light-conducting structure being interrupted at at least one arm.

~~Brief Description of the Drawings~~

~~The present invention is elucidated in the following on the basis of exemplary embodiments, with reference to the drawing. The figures show:~~ Brief Description of the Drawings

Figure 1 shows a schematic representation of an overall construction of an interferometric measuring device having a modulation interferometer and a measuring probe₇.

Figure 2 shows a more detailed illustration of an example
5 embodiment of the modulation interferometer shown in Figure
1₇1.

Figure 3 shows a side view of the measuring probe and the
measured object ~~in a side view~~ with a representation of the radiation error in offset₇.

10 Figure 4 shows a schematic side-view representation of a fiber part of the measuring probe ~~in a side view~~₇.

Figure 5 shows a schematic illustration of the front section
of the measuring probe ~~in a schematic lateral representation~~
and.

15 Figure 6 shows a schematic illustration of a further
exemplary example embodiment of the front section of the measuring probe ~~in a schematic lateral representation~~.

~~Exemplary Embodiment~~ Detailed Description

As shown in Figure 1, the interferometric measuring device
20 ~~based on~~ using the principle of heterodyne interferometry has a broad-band, short-coherent light source 1, whose radiation is supplied to a so-called modulation interferometer 2. In modulation interferometer 2, which is shown in greater detail in Figure 2, radiation $s(t)$ is split ~~up~~ at a first beam
25 splitter 2.3 into a first beam component 2.1 guided via a first arm, having a partial radiation $s_1(t)$, and a second beam component 2.1' guided via a second arm, having a partial radiation $s_2(t)$, ~~and is.~~ The two beam components are
recombined at the exit side at an additional beam splitter
30 2.10, and from there ~~it~~ the recombined beam is conducted via a

light-conducting fiber device 6 to a distant measuring probe 3. From measuring probe 3, which is constructed, for example, as a Fizeau interferometer or a Mirau interferometer, ~~as is explained in more detail in the documents named at the outset,~~
5 the radiation subsequently reaches, via an additional light-conducting fiber device 7, a receiver device 4 having a beam splitting unit 4.1 and subsequent downstream photoelectric receivers 4.2, in which a conversion into electrical signals takes place. In a subsequent downstream evaluation unit 5,
10 having a phase detector 5.1 and a computing unit 5.2, the properties of the measuring surface picked up using measuring probe 3 (such as roughness, shape, clearance distance) are then ascertained.

Modulation interferometer 2 is designed as a Mach-Zehnder
15 interferometer, the two arms in connection to first beam splitter 2.3 having first and second entrance-side light-conducting fibers 2.11, 2.11', and first and second exit-side light-conducting fibers 2.12, 2.12', which lead to additional beam splitter 2.10. First beam splitter 2.3 is, in this case,
20 formed in an optical fiber, by which the radiation coming from light source 1 is advanced. At the exit of the coupler thus formed, the beam components are collimated with the aid of lens-type coupling elements 2.4, 2.4', and the two collimated beam components pass through a first or a second modulating
25 unit 2.2, 2.2', ~~for instance,~~ in the form of, e.g., an acoustooptical modulator, a fiber optic piezo modulator or a thermal phase modulator, the modulating units 2.2, 2.2' being advantageously able to be developed also as integrated optical components. In order to correct the chromatic dispersion, at
30 least one of beam components 2.1, 2.1' passes through a glass plate 2.7' which is situated in a first or a second light path ~~2.5, 2.5'~~. The choice of the positioning of the glass plate ~~2.7'~~ and/or its thickness is determined by calculation. In

their further course, first beam component 2.1 and second beam component 2.1' are conducted to a first or a second lens-type light guide element 2.6, 2.6' and coupled into the first or the second exit-side light-conducting fiber 2.12, 2.12'. First ~~or~~and second exit-side light-conducting fiber 2.12, 2.12' ~~has a greater~~have different optical path length ~~than the other light-conducting fiber,~~lengths to the extent that the optical path difference $\Delta L = L_2 - L_1$ between the two arms is greater than the coherence length of the short-coherent radiation $s(t)$ ~~after running through filters 4.3 and 4.3'.~~ One of the lens-type coupling elements 2.4, 2.4' or light-conducting elements 2.6, 2.6', for example, light-conducting element 2.6', may be fastened to a calibrating device, using which the optical path difference ΔL may be adjusted, by hand or with the aid of a motor, for instance, while using a micrometer bench, in such a way that the path difference ΔL between the two arms is tuned to that of measuring probe 3 so as to effect interference using measuring probe 3. Light-conducting fibers 2.11, 2.11', 2.12, 2.12' used are monomode. Besides, they ~~are advantageously~~may be polarization-receiving, especially if light source 1 is polarized and/or if modulating units 2.2, 2.2' are formed of double-refractive crystals and/or if installation at the coupling locations does not yield satisfactory stability with respect to the polarization direction in the two interferometer arms. To achieve the optical path difference, an optical alternate route (delay line) 2.9' is provided, for example, in second exit-side light-conducting fiber 2.12'.

Probe 3, which is used to detect the object surface, which probe is designed, for instance, as a Fizeau interferometer or a Mirau interferometer, has a reference branch having a reference plane and a measuring branch leading to the object surface, ~~whose~~optical path differences of which two branches

are selected so that the path difference generated in modulating interferometer 2 is compensated for, so that the measuring beam coming from the object surface and the reference beam coming from the reference plane interfere when they are superposed. The interfering radiation is supplied to beam splitting unit 4.1 for spectral partitioning into components of different wavelengths, and ~~is the split~~ components are subsequently supplied to the allocated photoelectric receivers 4.2. The desired surface property is ascertained from the interfering radiation and the electrical signals obtained from it by evaluating the phase differences, by using phase detector 5.1 and subsequent computing unit 5.2. In this context, the evaluated phase difference is created by the frequency difference, generated by first or second modulating unit 2.2, 2.2', which, corresponding to the heterodyne method, is relatively low with respect to the fundamental frequency. The calculation is carried out according to the formula:

$$\Delta\varphi = 2\pi \cdot (2e/\Lambda) + \varphi_0$$

where

φ_0 is a constant,

$\Lambda = \lambda\lambda_1 \cdot \lambda\lambda_2 / (\lambda\lambda_2 - \lambda\lambda_1)$ is the synthetic wavelength of the measuring device,

$\lambda\lambda_1$ is the wavelength at a first photoelectric receiver,

$\lambda\lambda_2$ is the wavelength at a second photoelectric receiver,
e is the measuring distance.

From this, using evaluation unit 5, the respective recorded clearance distance of the surface at a measuring point is determined from the relationship:

$$e = \Delta\varphi \cdot (2\pi) \cdot (\Lambda/2)$$

Distance measure e is thus determined from a measurement of the phase between two electrical signals, and therefore the measurement is independent of the optical intensity received by the photodiodes.

5 Figure 3 shows a fiber part of the measuring probe, e.g., designed as a Mirau interferometer, having a monomode light-conducting fiber, and the path displacement of the incident radiation $s_2(t)$ and $s_1(t)$, as well as the retracing radiation components $r_1'(t)$, $r_1(t)$, $r_2(t)$ and $r_2'(t)$ from the surface of
10 measuring object 8 and a partially transmitting region 3.3 between an object-side exit surface 3.31 (see Fig. 4) of a probe fiber 3.1 and an entrance surface ~~3.32~~, 3.32 (see Fig. 4), farther away from the object, of a fiber section 3.2. The retracing portions of radiation $r_1'(t)$ and $r_1(t)$ come about, in
15 this context, from ~~that~~ the radiation $s_1(t)$ which has passed through the arm of modulating interferometer 2 without the alternate route, portion of radiation $r_1'(t)$ being reflected by partially transmitting region 3.3 and portion of radiation $r_1(t)$ being reflected by the surface of measured object 8. By
20 contrast, the retracing portions of radiation $r_2(t)$ and $r_2'(t)$ come about from ~~that~~ the radiation $s_2(t)$ of modulating interferometer 2 which has passed through the optical alternate route, retracing portion of radiation $r_2(t)$ having being
25 retracing portion of radiation $r_2'(t)$ having being reflected by the surface of measured object 8. It is shown that, corresponding to the compensation of the path difference $\Delta\Delta L$ formed in modulating interferometer 2 by measuring probe 3, only the retracing portions of radiation $r_1(t)$ and $r_2(t)$ lie
30 within the coherence length and interfere with each other.

In the exemplary embodiment as shown in Figure 3, object-side exit surface 3.4 of fiber section 3.2 is inclined ~~preferably~~ at an angle of 45° with respect to optical probe axis 3.5. A

reflective metallic or dielectric coating is applied to exit surface 3.4. The radiation is bent in this manner essentially at a right angles and guided to the surrounding surface of the object, and the radiation reflected by the surface
5 reenters the light-conducting fiber via exit surface 3.4.

As shown in Figures 4 to 6, partially transmitting region 3.3 is formed between exit surface 3.31 of probe fiber 3.1 and entrance surface 3.32 of fiber section 3.2 by an inclination of exit surface 3.31 at an angle α with respect to the
10 normal of probe axis 3.5, and by an inclination of entrance surface 3.32 of fiber section 3.2 at an angle β with respect to the normal of probe axis 3.5, the angle α being greater than the angle β , and a wedge-shaped gap ~~coming about~~ formed between the exit surface 3.31 and the entrance surface 3.32.

15 The alignment of the inclination with respect to the normal is oriented in the same manner towards the object in the case of exit surface 3.31 and entrance surface 3.32. Angle α of exit surface 3.31 is selected so that the radiation flow of the Fresnel reflection on exit surface 3.31 is not guided by
20 probe fiber 3.1. For a monomode light-conducting fiber having a numerical aperture of 0.12, the angle α is advantageously about 6° . Angle β is selected so that the radiation flow of the Fresnel reflection is guided onto entrance surface 3.32 of fiber section 3.2 by probe fiber 3.1, the extent of the
25 radiation flow that is to be coupled into probe fiber 3.1 being taken into consideration. If angle β is equal to 0° , the coupling rate amounts to about 3.6 %. If angle β runs counter to angle α , the degree of coupling tends toward 0. If angle β tends counter to angle α , the transmission for
30 this transition and a retracing radiation goes toward 86 %. If, however, angle β is equal to 0° , the transmission amounts to about 60 %. A numerical aperture of 0.12 ~~comes~~

~~about~~results, for example, at a wavelength of 1.550 nm and a diameter of 10.4 μm . Angle α should not be selected to be less than about 5° .

The reflection treatment of exit surface 3.4 of fiber section 3.2 may be reduced or avoided if exit angle γ (see Fig. 4) is increased so as to achieve total reflection at exit surface of 7. This is the case, for instance, in the case of a monomode light-conducting fiber having a numerical aperture of 0.12, at an exit angle γ that is above 48° .

At the object-side end region of fiber section 3.2, an anti-reflection treatment 3.22 may be ~~undertaken~~provided on the outer ~~treatment~~surface (cladding), in order to reduce the sensitivity with respect to the Fresnel reflection, or exit angle γ may be enlarged to the extent that the radiation flow of this reflection is no longer coupled into fiber section 3.2.

As shown in Figure 5, probe fiber 3.1 and fiber section 3.2 may be accommodated in the same tubule-type accommodation 3.6 and brought into contact. Accommodation 3.6 is the same that is used for connectors of monomode light-conducting fibers. Accommodation 3.6 is inserted into a tube 3.9 of the measuring probe 3 that surrounds it. On the inside of tube 3.9, on the end face of accommodation 3.6 lying away from the object, there is subsequently also a positioning piece 3.7 for guiding and preadjusting probe fiber 3.1. Fiber section 3.2 is fixed on the inside of the accommodation with the aid of adhesives 3.8', while probe fiber 3.1 is fixed in accommodation 3.6 and/or positioning piece 3.7 with the aid of adhesives 3.8.

Another procedure for aligning and fixing probe fiber 3.1 and fiber section 3.2 in probe 3 is shown in Figure 6. Probe

fiber 3.1 is introduced into a rear section 3.6' of tubule-type accommodation 3.6, and the front end face of ~~accommodation~~rear section 3.6' and of exit surface 3.31 of probe fiber 3.1 are polished at the desired angle, the front end face in the region of the front-most edge of probe fiber 3.1 being aligned normal to optical axis 3.5 of probe fiber 3.1. Accordingly, the rear end face of a front section 3.6" of accommodation 3.6 is polished corresponding to the desired entrance surface 3.32 of fiber section 3.2, the region of the rear end face of front section 3.6" of accommodation 3.6, which is adjacent to the hindmost edge of fiber section 3.2, being aligned normal to optical axis 3.5 of probe fiber 3.1. Between rear section 3.6' and front section 3.6" of accommodation 3.6 there comes about, in this context, the set-up shown in Figure 6 in longitudinal section. The two sections 3.6' and 3.6" of accommodation 3.6 are axially aligned with each other using a retaining ring 3.10 that is applied, for example slotted, and inserted into tube 3.9. Furthermore, in tube 3.9 there is also inserted, in turn, bordering on the rear end face of accommodation 3.6, a concentric positioning piece 3.7 for calibrating and prefixing probe fiber 3.1, as in the exemplary embodiment according to Figure 5. The fixing of probe fiber 3.1 and of fiber section 3.2 using adhesives 3.8, 3.8' thus also takes place corresponding to the exemplary embodiment according to Figure 5, fiber section 3.6 being fixed in front section 3.6" of accommodation 3.6.

It is also possible to align sections 3.6' and 3.6" by inserting them into a V-shaped profile. Because the two sections 3.6', 3.6" of accommodation 3.6 are inserted separately, the outermost end of measuring probe 3 may be changed immovably and corresponding to the characteristic of the measured object, the same probe fiber 3.1 being retained.

As Figures 4 to 6 also show, the outer section of fiber section 3.2 is reduced in its diameter, so that it may also be introduced into tight holes of a measured object 8, whose diameter amounts to less than 130 μm , for example. The diameter of a monomode light-conducting fiber having outer treatment (cladding) usually amounts to 125 μm . The diameter may be reduced with the aid of chemical treatment using an appropriate acid or of heat treatment, so as to obtain a desired tapering 3.21. Antireflecting treatment 3.22 is then undertaken in the region of the section of lower diameter. These measures, too, contribute to ~~one's being able to~~ability to undertake reliable measurements even in tight recesses of a measured object 8.

The ~~present invention relates to an~~ An interferometric measuring device for recording the shape, the roughness or the clearance distance of the surface of a measured object ~~(8) is provided, the measuring device~~ having a modulating interferometer ~~(2)~~, to which is supplied short-coherent radiation by a radiation source ~~(1)~~, and which has a first beam splitter ~~(2.3)~~ for splitting the radiation supplied into a first beam component ~~(2.1)~~ guided via a first arm, and into a second beam component ~~(2.1')~~ guided via a second arm, ~~of which the one. One beam~~ is shifted with respect to the other beam, with the aid of a modulating device ~~(2.2, 2.2')~~, in its terms of the beam's light phase or light frequency, and passes through a delay line ~~(2.9')~~, ~~and which. The two beams~~ are subsequently combined at an additional beam splitter ~~(2.10)~~ of the modulating interferometer ~~(2)~~, ~~having a. A~~ measuring probe ~~(3)~~ that is spatially separated from the modulating interferometer ~~(2)~~ and is coupled to it or able to be coupled to it via a light-conducting fiber set-up ~~(6)~~, in which probe the combined beam components are split into a measuring beam guided to the surface by a probe-optical fiber unit ~~(3.1, 3.2)~~ having a slantwise exit surface ~~(3.4)~~ on the object side and a reference beam, ~~and in which the measuring beam $(r_1(t))$ reflected at the surface and the reference beam $(r_2(t))$ reflected at a reference plane are superposed,~~ and ~~having a receiver device (4) and an evaluating unit (5) for converting the radiation supplied to it into electrical signals and for evaluating the signals on the basis of a phase difference,~~. An accurate surface measurement is ~~facilitated~~ by the angle of inclination ~~(γ)~~ of the exit surface ~~(3.4)~~ to the normal of the optical probe axis ~~(3.5)~~ amounting to at least 46° . ~~(Fig. 4)~~